Observations on Yellow-bellied Sheath-tailed Bats *Saccoliamus flaviventris* (Peters, 1867) (Chiroptera: Emballonuridae)

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ABSTRACT

The felling of a tree at Brightview, south-west of Brisbane containing a colony of 29 *Saccoliamus flaviventris* provided an opportunity to obtain data on morphology, ectoparasites, and sex ratios from 13 individuals killed during the tree felling. This is the largest known colony of this species. The limited availability of roost trees may be the cause of this large aggregation of bats. The importance of checking mature or dead trees prior to felling is demonstrated by the number of bats in this colony. Comparison of wing morphology showed no significant difference between the sexes, but significant differences occurred between bats from Brightview and Mt. Isa. Incidental observations on echolocation call structure and flight behaviour are also presented. The dimensions of the wings of *S. flaviventris* are similar to *Nyctinomus australis*, resulting in similar flight patterns for these species. Both species fly straight and rapidly above the canopy, although observations suggest they fly at different times of night, possibly due to differences in prey type.

INTRODUCTION

Despite being widespread over much of Australia, information on the biology of *Saccoliamus flaviventris* is scant, particularly details on roost dynamics. This can be attributed to a combination of its rarity throughout its distribution and the difficulty in capturing individuals (Reardon and Flavel 1987; Richards 1995). Although this bat is considered difficult to capture using mist nets and harp traps, most observations of its flight behaviour are unequivocal. *S. flaviventris* flies fast above the canopy level (Reardon and Flavel 1987; Parnaby 1992; Wilson *et al.* 1993; Richards 1995), usually in a straight flight path with slow wing beats (Reardon and Flavel 1987). The long, narrow wings of this species are responsible for this observed flight behaviour (Dwyer 1965; McKenzie and Rolfe 1986).

Saccoliamus flaviventris is the largest member of the family Emballonuridae in Australia, with a forearm length of 74–77 mm and body weight of 30–60 g (Richards 1995). Compared to other microchiroptera in Australia, its taxonomy has remained fairly stable. This can be attributed to the taxonomic work of Troughton (1925). Because of this bat's distinct fur colouration (jet black dorsally, pure to creamy white ventrally) and the tail protruding from the dorsal surface of the tail membrane, its identification is relatively easy, either in flight or in the hand (Hall and Richards 1979; Reardon and Flavel 1987; Richards 1995). Male *S. flaviventris* have a distinctive throat pouch in close proximity to a sebaceous gland, the function of which has been postulated to be for territorial marking (Hall and Gordon 1982).

This paper presents information on a tree colony of *S. flaviventris* and records observations on the capture and flight behaviour of this species in Queensland.

MATERIALS AND METHODS

Brightview colony

A colony of 29 *S. flaviventris* was obtained during the felling of a 20 m high dead tree at Brightview, (27°29'S, 152°31'E), near Laidley in south-east Queensland, on 26 April 1996. The colony was discovered accidentally when the tree, located in open grazing land, was being cut into sections for firewood after felling. Thirteen individuals were killed either as a result of felling or cutting of the tree. Data on morphometrics, parasites and reproductive status were obtained from each of these deceased bats. The 13 dead specimens are now in the Queensland Museum (Nos. JM11418 to JM11430), and the surviving 16 individuals were released near the point of capture.

The age, sex and reproductive condition of the bats was examined and recorded in the field. Ectoparasites, collected from the 13 dead specimens with the aid of fine forceps, were stored in 90% ethanol. Identification of ectoparasites was based on the characters discussed in Klompen (1992). Body mass of the bats was measured to the nearest 0.1 g with an electronic balance. Measurements of morphometric characters were made to the nearest 0.1 mm with dial callipers. Measurements included length of ear, forearm, and metacarpal and phalangeal elements in digits III, IV and V. The outline of the right half of each bat with the

wing fully extended was traced on to paper using the method described by Rhodes (1995). The area traced was calculated using a Calcomp digitizer tablet connected to a MacIntosh computer running "Image 1.49" image analysis programme (National Institute of Health, USA). Wing loading, aspect ratio, and wing tip ratios were derived using calculations as in Rhodes (1995). Morphometric data were also obtained from captures of three *S. flaviventris* on the Djarra Road, 15 kilometres south of Mt. Isa (20°52'S, 139°28'E).

Flight observations and call recordings

Observations on the flight of *S. flaviventris* were made at five locations. In July 1988, at Cape Tribulation National Park (16°09'S, 145°27'E); September 1993, at Southwood National Park (27°50'S, 150°07'E); on a number of occasions between 1985 and 1996 at Moggill (27°34'S, 152°52'E); on Fraser Island (25°26'S, 153°05'E) in January 1995; and at Karawatha Forest (27°40'S, 153°09'E) between January and March, 1995. On each occasion observations were made with a 50 or 100 watt hand-held spotlight. At Cape Tribulation the bats were observed flying over low mangroves and the tidal estuary of Noah Creek. At Southwood the observations were over an isolated stock dam in low open forest; and the Moggill observations were in cleared land along a road and along the banks of the Brisbane River. At Karawatha Forest, *S. flaviventris* was observed flying over a remnant tall eucalypt forest surrounded by urban development.

Recordings of the ultrasonic calls of *S. flaviventris* were made using either a QMC S25 (Ultrasound Advice, London) or an Anabat II detector (Titley Electronics, Ballina, New South Wales). Calls were recorded on a hand-held cassette recorder (Realistic VSC-2001, Tandy Electronics), and the Anabat recorded tapes were later analysed using Anabat II software (Titley Electronics, Ballina, New South Wales) on a PC computer. Recordings of *S. flaviventris* echolocation calls were made on Fraser Island and at Karawatha Forest.

Additional records

Two live, but non-flying *S. flaviventris* were handed to the University of Queensland veterinary clinic in May 1993 and August 1996. They were found on the ground in suburban Brisbane. Both were males and were in a poor state of health and died within two weeks.

RESULTS

Brightview colony

Roost description

The colony containing 29 *S. flaviventris* was in a hollow *Eucalyptus* sp. which had been dead for at least 10 years. The tree was 20 m high and the roost was located 4 m from the top, with the exit facing west. The advanced state of decay made detailed measurements of the tree inaccurate after felling. The area immediately surrounding the roost tree had been extensively cleared recently, being in a paddock used for grazing. The roost tree was approximately 25 m from other trees, these being isolated stands of *E. bloxsomei* and *E. drepanophylla*.

Age and reproductive condition

Each of the three males in the colony were adult, the only sub-adults present were two of the ten females. None of the females were pregnant or lactating, and seven out of the ten, including the two sub-adults, were nulliparous.

Table 1. Comparison of morphological characters between male and female *S. flaviventris* from Brightview (n = 13). Data are from direct measurement of characters. Values indicate mean and standard deviations, with t-test probability shown or ns indicating no significant difference. Figures for mass are in grams, other measurements are in millimetres.

Character	Male (n = 3)	Female (n = 10)	P (t-test)
Mass (g)	51.43 ± 3.59	54.78 ± 5.31	ns
Ear length (mm)	17.53 ± 2.06	18.10 ± 1.72	ns
Fore arm (mm)	76.70 ± 2.43	77.10 ± 1.47	ns
Digit 3 metacarpel	79.73 ± 2.54	79.29 ± 2.12	ns
Digit 3, phalanx 1	34.60 ± 0.26	33.63 ± 1.57	ns
Digit 3, phalanx 2	33.27 ± 1.10	32.87 ± 1.12	ns
Digit 4 metacarpel	62.23 ± 2.79	62.19 ± 2.09	ns
Digit 4, phalanx 1	20.47 ± 0.06	19.25 ± 1.16	$<$0.01
Digit 4, phalanx 2	7.87 ± 0.21	7.60 ± 0.94	ns
Digit 5 metacarpel	50.23 ± 2.33	49.80 ± 2.18	ns
Digit 5, phalanx 1	17.83 ± 0.50	17.60 ± 1.08	ns
Digit 5, phalanx 2	10.63 ± 1.77	10.74 ± 0.77	ns

Table 2. Comparison of derived morphological characters between male and female *S. flaviventris* from Brightview (n = 13). Data are from wing tracing calculations of wing area. Values indicate mean and standard deviations, with t-test probability shown or ns indicating no significant difference.

Character	Male (n = 3)	Female (n = 10)	P (t-test)
Mass (kg)	0.0514 ± 0.0036	0.0548 ± 0.0053	ns
Wingspan (m)	0.5173 ± 0.0081	0.5124 ± 0.0182	ns
Wing area (m^2)	0.0324 ± 0.0022	0.0319 ± 0.0022	ns
Wing loading (N/m^2)	15.64 ± 2.00	16.92 ± 2.17	ns
Aspect ratio	8.27 ± 0.35	8.25 ± 0.51	ns
Wing-tip length ratio	1.04 ± 0.06	1.05 ± 0.06	ns
Wing-tip area ratio	0.56 ± 0.05	0.55 ± 0.05	ns
Wing-tip shape index	1.15 ± 0.06	1.09 ± 0.12	ns

Table 3. Comparison between morphological characters of *S. flaviventris* at Brightview (n = 13) and Mt. Isa (n = 3; all female). Values indicate mean and standard deviations, with t-test probability shown or ns indicating no significant difference.

Character	Brightview	Mt. Isa	P (t-test)
Forearm length (mm)	77.0 ± 1.619	74.5 ± 0.283	<0.001
Mass (kg)	0.054 ± 0.005	0.041 ± 0.002	<0.001
Wingspan (m)	0.514 ± 0.016	0.512 ± 0.006	ns
Wing area (m^2)	0.032 ± 0.002	0.027 ± 0.001	<0.001
Wing loading (N/m^2)	16.621 ± 2.123	14.985 ± 0.636	ns
Aspect ratio	8.255 ± 0.461	9.752 ± 0.171	<0.01
Wing-tip length ratio	1.050 ± 0.060	1.099 ± 0.072	ns
Wing-tip area ratio	0.550 ± 0.047	0.516 ± 0.041	ns
Wing-tip shape index	1.103 ± 0.112	0.885 ± 0.024	<0.001

Morphometric data

The means of each of the directly measured morphological characters by sex are shown in Table 1. There was no significant difference between sexes in size of characters, with the exception of the first phalanx of the fourth digit. The forearm length ranged from 75.2–80.1 mm, which is close to the range of 74–80 mm given by Richards (1995), and at the higher end of the 70–80 mm range given by Troughton (1925). Although females had greater mass, forearm length and ear length, males had greater lengths of all but one of the wing elements. The highest variability in measurements occurred in ear length and body mass, as indicated by the standard deviations. The body mass of females was particularly variable, most likely as a result of different age classes.

Measurements of morphological characters obtained from wing tracing data are shown in Table 2. No significant difference occurred between sexes in any character. Males had slightly larger wingspan and wing area, while females had slightly higher wing loading due to their generally greater mass and smaller wings. The aspect ratio and wing loading figures are similar to data for *S. flaviventris* reported by McKenzie and Rolfe (1986), but slightly higher than Norberg and Rayner (1987). The aspect ratio is slightly lower than that reported for *S. flaviventris* by Dwyer (1965). The variation between published wing characteristics and those found in the present study may be due in part to differences in methods of measurement. In a survey of wing morphology of 23 south-east Queensland bat species by Rhodes (unpubl. data), *S. flaviventris* had the highest wing aspect ratio, and the third highest wing loading. The wing loading and aspect ratio closely resemble that of *Nyctinomus australis*.

A comparison of morphometric data for *S. flaviventris* from Brightview and Mt. Isa is shown in Table 3. *S. flaviventris* from Mt. Isa have significantly smaller forearm length, body mass and wing area, but have wings of similar length, resulting in a lower wing loading and a significantly higher aspect ratio. Although the sample size from Mt. Isa is small, these differences in wing suggest geographical variation in wing morphometry occurs within the species.

Ectoparasites of S. flaviventris

The only ectoparasites found on *S. flaviventris* from Brightview were the larval form of one species of tick, *Carios* species (Subfamily Ornithodorinae, family Argasidae). These were identifiable only to generic level as only larvae were present. Eleven of the thirteen bats had tick larvae, in numbers ranging from 1 to 19 per bat. Each of the three males had one tick larvae, and the eight females had between 1 and 19 tick larvae. Females had a significantly greater number of tick larvae (mean 6.6 ± 6.9; T-test p = 0.03). There were no trends apparent in number of ticks by mass, age class or reproductive condition.

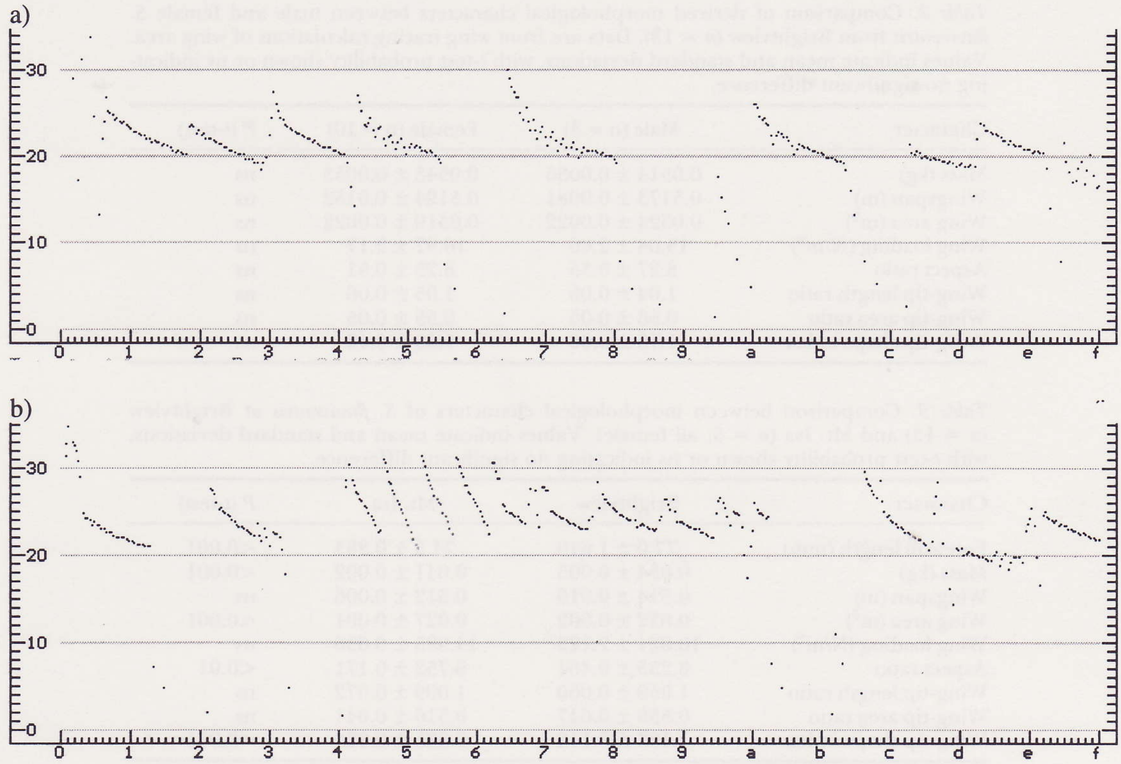

Figure 1a and 1b. Example of Analook 2.0 sonographs of *S. flaviventris* echolocation calls. The vertical axis represents frequency in kiloHertz, and horizontal axis represents time with each major interval equal to 10 milliseconds. Both call sequences are from Karawatha Forest on 24/3/95. Call sequence 1a shows shallow echolocation calls, and 1b steeper calls, possibly associated with insect pursuit.

Flight observations and call recordings

On most occasions *S. flaviventris* flew between 3 and 20 m above the ground and rarely made any deviations from a very direct flight path. This flight pattern, combined with the white belly fur, and a distinctive fluttery wing beat, made *S. flaviventris* easy to identify and observe in flight. The capture of three specimens at 1.5 m above the ground near Mt. Isa was probably due to the bats coming in to drink at a nearby waterhole. At Cape Tribulation, *S. flaviventris* were observed flying a metre or so above the mangroves and occasionally close to the water surface. On several occasions an aerial pursuit involving two bats was observed. During the pursuit, one bat followed about 1 to 2 m behind another bat, and they flew in a zig-zag pattern about 2 to 3 m above the ground. These flights lasted up to 30 seconds and were accompanied by constant vocalizations. At the end of a chase the bats returned to foraging at an estimated height of about 20 m.

In open country, such as at Moggill, and along the Brisbane River, *S. flaviventris* was observed flying at a constant height estimated to be 15 to 20 m above the ground and, by following in a vehicle, the bats were estimated to fly at about 25 to 30 km per hour. Similar observations were made at Karawatha Forest, where *S. flaviventris* were regularly seen at least one hour after sunset, flying with few deviations high above the canopy at an estimated height of 20 to 25 m. At Fraser Island, *S. flaviventris* were recorded by ultrasonic detection between 20:00 and 21:00 hours on 19 January 1995, but not seen.

At Southgate, *S. flaviventris* were recorded flying at an estimated height of 25 m above a stock dam at 2200 hrs. In the earlier part of the night, numerous White-striped mastiff-bats *Nyctinomus australis* were active around the stock dam, and were mist-netted while coming in to drink. They were not present when *S. flaviventris* appeared.

Examples of echolocation calls of *S. flaviventris* at Karawatha Forest are presented in Figure 1. The cruise phase calls consist of a shallow, curved FM sweep, descending in frequency. Some sequences containing steeper calls were recorded (Figure 1b) which may represent feeding buzzes. The steeper calls span a slightly greater range of frequencies, and had lower duration and time between calls (Table 4). The characteristics of cruise and shallow calls are shown in Table 4. Components of the call are audible to humans, and sound like a repetitive, high-pitched bird-like chirp.

Table 4. Characteristics of echolocation calls of *S. flaviventris*. Data from sequences illustrated in Figure 1. Figures are means generated by Anabat software.

Character	Cruise calls (i.e., Figure 1a)	Steep calls (i.e., Figure 1b)
Start frequency (kHz)	28	33.5
End frequency (kHz)	19.5	22.5
Call duration (ms)	15.2	5.19
Time between calls (ms)	379	79.6

Additional records

There were no obvious ectoparasites or injuries on the two *S. flaviventris* found on the ground in suburban Brisbane. Body weights of these two bats were 32 and 38 g and they made no attempt to fly. During their short period of confinement they drank very little water and proved to be difficult to feed on mealworms, moths or dog food. Autopsies performed on the bats following their death revealed that they both had infected gums, and their mouths and teeth were darkly stained. The molars on both specimens were worn almost to the gumline. It was not determined whether the condition of the oral cavity was due to attempts to feed the bats in captivity or if it was responsible for their poor health. No obvious cause of their deaths could be determined.

In a dry creekbed 15 km south of Mt. Isa on the Djarra Road (20°52′S, 139°28′E), three *S. flaviventris* were captured in a mist net between 1830 and 1900 hours on 25 September 1993. Morphometric data were obtained from wing tracing and measuring these bats. The net was set at ground level under the branches of a 6 m high River Red Gum *Eucalyptus camaldulensis*, which was growing in the watercourse. The site was 20 m from an open waterhole which was approximately 6 m in diameter and 0.6 m deep. The surrounding country was dominated by Snappy Gum *E. brevifolia* on low stony hills covered by Spinifex *Triodia pungens*. A thunderstorm had filled the waterhole earlier in the afternoon.

DISCUSSION

The appearance of *S. flaviventris* is distinctive, not only because of its coloration, but its large size and long, narrow wings. These morphological characteristics are responsible for the species characteristic flight behaviour. Rapid flight with low manoeuvrability are associated with high body mass and long, narrow wings (Pennycuick 1975; Norberg 1981). This flight style is best suited to flight in very open areas well away from obstacles, such as above the canopy in a forest, or at lower heights in unforested areas. Our observations of *S. flaviventris* flight behaviour, and those from previous studies support this association between morphology and behaviour. McKenzie and Rolfe (1986) observed *S. flaviventris* above the canopy and in open areas next to vegetation. Wilson *et al.* (1993) described a very large bat that was flying high with a pale underside that was probably *S. flaviventris*. Our observations were similar, with *S. flaviventris* observed most often flying about 15 to 25 m above the ground with few deviations from a straight flight path.

The flight behaviour described for *S. flaviventris* is similar to *N. australis*, which has similar wing morphometry. Dwyer (1965) found *S. flaviventris* had the closest aspect ratio and wing loading to *N. australis*, but both characters were less extreme, which was predicted to give slower, more manoeuvrable flight. The aspect ratio and wing loading was found to be very close to that of *N. australis* by Rhodes (unpubl. data). The similar wing morphology of both species results in them having similar flight behaviour. Both species have rapid, direct flight suited to above canopy flight. In an open space, rapid flight enables prey to be encountered at a greater rate.

There is no published information on the echolocation calls of *S. flaviventris*, the only material available for comparison being reference calls from Anabat software. The echolocation calls of the *S. flaviventris* in this study are similar in shape to *N. australis* calls on Anabat software, but are about 10 kHz higher.

Some competition could be expected to occur between *S. flaviventris* and *N. australis* due to their similar size, wing morphometry and echolocation call. The observations at Southgate of *N. australis* foraging earlier in the evening than *S. flaviventris* suggest these species fly at different times. This may be a result of a change in prey density or type during the night. The favoured prey of *S. flaviventris* may emerge later in the night compared to that of *N. australis*. Taylor and O'Neill (1988) suggest that the height of insect prey decreases with time after sunset. If this is the case, *S. flaviventris* may be better suited than *N. australis* for foraging at low prey densities above the canopy. Vestjens and Hall (1977) found Orthoptera (grasshoppers), two Coleoptera (chafers), and a Hemiptera (bug), in the stomachs of three *S. flaviventris* in the Northern Territory. Coles and Lumsden (1993) found only beetles in the stomachs of *S. flaviventris* from Cape York. While these were small samples from localities outside of southern Queensland, they differ to *N. australis*, which was found to have predominantly Lepidoptera (moths) in the stomachs of 21 individuals from three localities outside of Queensland (Vestjens and Hall 1977).

S. flaviventris from Mt. Isa is smaller than from Brightview in all characters other than wingspan. This means their wings are relatively

longer and more narrow, with more pointed tips. Although the sample size from Mt. Isa is small, it suggests geographical variation in the species. Although geographical variation was not further examined in the present study, measurements of 21 characters from 10 localities by Troughton (1925) indicate geographical variation does occur in *S. flaviventris*. The flight behaviour of *S. flaviventris* at Mt. Isa may differ from in south-east Queensland as a result of the morphological variation. The longer more narrow wings may give more economical, enduring flight. The capture of *S. flaviventris* close to the ground near Mt. Isa suggests that there could have been a roost hollow in the *E. camaldulensis* overhead, or the bats may have been coming down to drink at the nearby waterhole. The vocalizations of the first captured specimen may have also attracted the other two bats.

There is speculation that *S. flaviventris* is migratory, based on collection locality records occurring during one part of the year only (Reardon and Flavel 1987; Richards 1995). The long, narrow wings described in this study would appear suited to migration. However, the patterns of seasonal fat deposition observed in the species by Chimimba and Kitchener (1987) indicate that migration may not occur. The large colony of both sexes found at Brightview may indicate that clustering is a winter behaviour. The greater numbers of ectoparasites on female *S. flaviventris* in the Brightview roost may be a result of sex differences in roost fidelity, or roost microhabitat choice.

The absence of pregnant or lactating females at Brightview in late April concurs with similar findings of Chimimba and Kitchener (1987) in north-west Australia, and suggest similar reproductive pattern occurs, with births occurring from December to March.

There is no information on mortality factors in *S. flaviventris*, nor for any Australian Emballonurid. Richards (1995) records that some *S. flaviventris* have been found in an exhausted condition on the walls of buildings, and make no effort to escape. The two specimens found on the ground in Brisbane were in a similar exhausted condition. There were no obvious injuries on these bats and only the poor state of their gums and teeth could be regarded as possible contributing factors to their deaths.

The colony of 29 *S. flaviventris* at Brightview represents the largest colony recorded for this species. Although few records of roosting behaviour and colony sizes for this species are available, Richards (1995) suggests this species is usually solitary, or in colonies of up to 10 individuals. Colonies with greater than 10 individuals may be rare or difficult to find, or may be occurring to an increasing extent as a result of shortage of roost trees. Each scenario demonstrates the importance of mature and dead eucalypts for *S. flaviventris* roosts. Other bat species show a preference for mature forest, containing trees with a diameter at breast height greater than 80 cm, for roosting (Lunney *et al.* 1985, 1988; Taylor and Savva 1988). Observations of trees at dusk may indicate the presence of bat species, but some species may emerge after darkness and be missed. Retention of mature and dead trees will provide potential roosts for this species, as well as a variety of other mammals and birds.

ACKNOWLEDGEMENTS

Thanks go to a number of people who assisted with aspects of this research. Nick Campbell identified the ticks from the Brightview bats and proof read an early draft of this paper. Thanks to Greg Richards and an anonymous referee for providing valuable comments on the manuscript. David and Ginney Locke of the Lockyer Valley fauna sanctuary obtained the bats from the Brightview residents who found the bats in the felled tree, recorded site details, released the live bats and passed the deceased bats on to us. Monika Feuser assisted with measurements and ectoparasite collection from the Brightview bats.

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BOOK REVIEWS — BOOK REVIEWS

"Name That Insect. A Guide to the Insects of Southeastern Australia" by T. R. New, 1996. Oxford University Press, Melbourne, Vic. 194 pp. RRP $19.95. ISBN 0 19 553782 3.

This is a most useful book for students, naturalists, teachers and those interested in the natural history of Australia and in particular, the entomological fauna of South Australia. As stated in the preface, this book is designed to introduce the insects of the region and to help people recognize some of the many kinds that are present. The author has included selected species of all orders, and used selected examples to illustrate their diversity and biology in southeastern Australia.

There are ten chapters and each has extensive line drawings to help the reader. An unusual feature of this book is that I could find only four references in the text proper, in Chapter 2 as footnotes and in Appendix 1 in the text. There is no reference list at the end of the book. There are three references in the preface and these seven are all the reader has to rely on to pursue subjects of interest further. This is not necessarily a criticism of the book but it is unusual to see such a lack of literature in a general introductory text.

Chapter 1, *The Diversity, Structure and Classification of Insects*, is a general introduction to the study of insects. It is here that the reader finds that most entomologists accept estimates of 5–10 million insect species worldwide (most of which are still unrecognized or formally described), and some believe that there could be up to 80 million species! These figures give an indication of just how little is known about the vast world of insects. The section on insect diversity is quite interesting and gives one some reasons why insects are so common, especially in the southern temperate regions, especially Australia and southern Africa. The section on body structure is necessary to understand terms used in subsequent chapters. It is a basic, uncomplicated discussion of various parts of insects and is supplemented with stylized but very useful line drawings. It is here that the reader should be aware that there is a glossary of mainly structural elements of insects at the back of the book and probably will be referred to extensively. The last section on classification is very basic indeed but will help people to better understand the concepts of orders, families, genera and species. Chapter 2, *Insect Diversity in Southeastern Australia*, briefly characterizes the boundaries of the area and discusses some of the enormous variety of natural environment in the area. The author carefully pointed out the often drastic effects of two centuries of European invasion and intensive land use upon native insect populations.

Chapter 3, *The Recognition of Insect Orders*, would be useful in any part of Australia. In his discussion, the author included true insects and three classes of allied near-insects, many of which are found commonly. Table 1 lists the classes of insects and related arthropods from the most primitive to the most advanced. Short descriptions of general habitats where each group may be found is included. Following the introduction, there is an interesting section on "why identify insects". It certainly goes well beyond " . . . the entrenched human desire to identify and compartmentalize elements of our natural world." For instance, the first element in control of insect pests is to find exactly which species is causing the problem. In many cases, proper identification of biological control agents may have great potential in affecting pest